PATENT SPECIFICATION

(11) 1 252 544

DRAWINGS ATTACHED

(21) Application No. 16970/70 (22) Filed 9 April 1970
(31) Convention Application No. 823 608 (32) Filed 12 May 1969 in
(33) United States of America (US)
(45) Complete Specification published 3 Nov. 1971
(51) International Classification F 01 d 5/02, 5/30
(52) Index at acceptance F1T 1A1 1B1 1E4 B2K

(72) Inventor JOSEPH ALBERT WAGLE

1252544

(54) TURBOMACHINE ROTORS

(71) We, GENERAL MOTORS CORPORATION, a Company incorporated under the laws of the State of Delaware, in the United States of America, of Grand Boulevard, in the city of Detroit, State of Michigan, in the United States of America (Assignees of JOSEPH ALBERT WAGLE) do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to turbomachine rotors and particularly to provide a strong, lightweight rotor for turbomachines such as axial-flow compressors and turbines.

The principal objects of the invention are to improve the strength and reliability of turbomachine rotors, to provide an improved rotor structure having light weight and adapted to exploit the advantages of lightweight metals such as titanium.

Figure 1 is a sectional view of a drum rotor taken in a plane containing the axis thereof;

Figure 2 is an enlarged view of a portion of Figure 1;

Figure 3 is a still further enlarged view corresponding to Figure 2 but illustrating the process of manufacture of the rotor;

Figure 4 is a radial sectional view taken on the plane indicated by the line 4—4 of Figure 2;

Figure 5 is a fragmentary axonometric view of a rotor ring; and

Figure 6 is a stress-strain diagram.

Figure 1 shows a rotor for a four-stage axial-flow compressor. The rotor comprises a drum 9 made up of four rings 10 and two end bells 11 and 13. As illustrated, the end bells are integral with stub shafts by which the drum may be mounted for rotation in suitable bearings, one stub shaft having a driving flange 14. The parts 10, 11, and 13 are held together by a tie bolt 15 and nut 17. The end bells may have any suitable shape and the tie bolt may or may not be present, depending upon the particular design.

As shown, the rings 10 progressively increase in diameter, although they may not and, in general, they are as near alike as feasible although they may differ in width and, ordinarily, in the number of blades mounted on the rings.

Each ring mounts a row of blades 18 having roots 19 which, as illustrated, are of the multiple clevis type embodying four clevis arms 21. As shown in Figure 4, each blade may embody a platform 22 between the aerofoil portion and the root. In the form illustrated, each ring 10 embodies a central blade mounting portion 23, two radial flanges 25, and axially extending marginal flanges 26.

The radial flanges contribute to the stiffness of the ring during its processing prior to the assembly into the rotor. However, these are not essential to the practice of the invention however desirable they may be in certain cases and, therefore, the ring 10 may, if desired, be a cylindrical or conical ring without offsets or radial flanges. The parts 23, 25, and 26 may be an integral machined part or, preferably, a welded or brazed structure made from a plurality of rings.

Since each blade root 19 comprises four arms 21, each ring is machined to provide four rows of apertures 27, with one aperture in each row for each arm 21. Semicircular holes 29 are machined through both flanges 25 to receive a semicircular blade retaining pin 30 having a head 31. Pin 30 may be retained in a suitable manner, as by centrifugal force in the conical structure illustrated, by pinning, by tack welding, or by adjacent rotor structure. The arms of the blade roots have holes 33 which are preferably cylindrical. Pin 30 extends through the holes 33 so as to mount the blade with a slight hinging action so that it may adopt a suitable position as a result of the centrifugal and gas loads in operation of the rotor. It is to be understood that such clevis and pin blade mountings are quite old and well known.

The features of the rotor described which are significantly different from prior rotors involve the reinforcing of the ring by a fibrous composite wrap 34, which is wrapped around the rotor in rings disposed between the arms 21

of the blade root, and the standoff ring or rings 35 disposed between the blade mounting portion 23 and the fibrous composite wrap 34. The materials used for the reinforcing wrap depending upon the nature of the installation. The use of glass fibers set by a thermosetting resin has been proposed. Currently there have been proposals involving more exotic materials such as sapphire, beryllium, tungsten, graphite, and boron filaments which may be bonded by a metal matrix or a suitable high strength polymer such as an epoxy resin for the lightest weight and greatest strength. The presently preferred materials for the reinforced rotor are titanium for the part 10 and a carbon or boron and epoxy resin composite for the reinforcing ring or wrap 34.

The standoff ring mentioned above, between the blade mounting ring and the reinforcing ring, comprises, in the preferred embodiment, three rings 35 disposed between adjacent arms 21 of the blade roots, the three rings extending around the perimeter of the blade mounting portion 23. Of course, it is possible to use a single ring provided with apertures for the blade mounting arms. However, as shown most clearly in Figures 3 and 4, the standoff ring is a thin ring of metal with corrugations extending axially of the rotor so that a spring slightly yieldable in radial direction, is provided between the rings 23 and 34 extending entirely around the rotor drum. This standoff ring may be made of steel or any other suitable material. The ring may be segmented with the segments located by cementing, brazing or otherwise fixing them to the ring 23.

The following technique has been devised for applying the several bands of the composite wrap 34. As illustrated in Figure 3, temporary flanges 37 are mounted, extending around the portion 23 of the mounting ring, and covering all four sets of the mounting apertures 27. The flanges 37 are rings of some material of sufficient strength to confine the wrap into the spaces between the blade root arms. These rings 37 are made of some material which may be removed readily after the winding curing of the reinforcing rings are completed as, for example, a soluble ceramic. According to this mode, the rings 37 are applied to the rotor and the standoff rings 35 are put into place, after which the fiber is applied with a suitable cement or binder and wound to the desired depth on the rotor, under appropriate tension. The fibre may be applied as a tape. The drum section or ring 10 is then cured and the rings 37 removed, after which the blades are inserted and the pins 30 applied to retain them.

It will also be clear, of course, that the reinforcing rings 34 might be wound around any suitable collapsing mandrel and then put or pressed into place on the ring 10. In this case, the ring 10 must not have a flange such as 25 extending so as to block the mounting of the reinforcing rings. The standoff rings 35 are provided to insure compatibility between the mounting ring and the reinforcing ring. This is illustrated by the stress-strain diagram in Figure 6. The line TI represents the elastic deformation of the titanium rotor with stress. The reinforcing ring deformation line indicated as WRAP starts at a considerable value of strain of the rotor because of clearance provided by the standoff ring. The line marked TOTAL represents the total stress exerted by the titanium ring and the wrapped reinforcing ring. This accommodates to the fact that the metal has a lower modulus of elasticity and, therefore, will yield to a greater extent than the fibrous composite. If the fibrous composite has a direct contact with the metal, the metal would be constrained by the fibre so as not to reach its maximum allowable stress. By allowing the metal to stretch farther than the wrap, both may be brought to the maximum allowable stress.

There is another factor that influences the need for the standoff ring: possible greater thermal expansion of the mounting ring 10 which causes it to expand more than the reinforcing ring as the rotor comes to its operating temperature. This, of course, depends upon both the materials and the temperature ranges involved.

It is clear, of course, that a ring such as 10 could mount more than one row of blades or, alternatively, that a drum such as 9 might be made as a unit rather than as a number of separate rings. The structure illustrated is preferred, however.

The rings may be coupled together into the rotor, to maintain them in proper alignment and to transfer torque between the rings, in various ways. They may be piloted together, coupled by face splines, or welded, for example.

The principal virtue of the embodiment described above lies in the felicitous use of the very high tensile strength fibrous composite wrap to reinforce the metal rotor drum against the very high centrifugal forces exerted upon it, principally by the blades, but also by the structure of the drum itself. The structure is such that the force exerted by the blades is delivered against the interior of the rotor drum, whereas the reinforcing ring is disposed about the exterior of the rotor immediately adjacent the point of application of the centrifugal forces from the blade roots.

The standoff ring allows some growth of the metal structure due to centrifugal force or temperature changes before the loads are transmitted fully to the fibrous reinforcement. This is desirable because of the usually greater yielding of the metal than of the fiber-reinforcement composite, so that to exploit the full strength of the metal it should be permitted to be strained to a greater extent than the reinforcement.

WHAT WE CLAIM IS:—

1. A turbomachine rotor structure comprising, in combination, a mounting ring, an annular row of blades mounted on the ring, the blades having clevis type roots with plural arms attached to the ring, a reinforcing ring of high tensile strength material disposed around the mounting ring between the arms, and a standoff ring which is disposed between the mounting ring and the reinforcing ring and allows some growth of the mounting ring relative to the reinforcing ring.

2. A structure as recited in claim 1 including pins disposed within the mounting ring extending through holes in the blade roots and coupling the blades to the ring.

3. A structure as recited in claim 2 in which the reinforcing ring is a fibrous composite wrap.

4. A structure as recited in claim 1 in which the standoff ring is defined by a strip of material shaped to be elastically yieldable in the radial direction.

5. A structure as recited in claim 4 in which the strip is corrugated.

6. A structure as recited in claim 4 in which the strip is segmented.

7. A structure as recited in claim 1 in which there are a plural number of reinforcing rings for each row of blades.

8. A turbomachine rotor comprising one or more drum sections of annular configuration and means mounting the section or sections for rotation about an axis, each drum section comprising a mounting ring, at least one annular row of blades distributed around the circumference of the ring, each blade having a clevis-type root defined by plural arms extending from the blade, the ring having apertures and the arms extending through the apertures to the interior of the ring, pins on the interior of the ring extending through holes in the arms to retain the blades and transmit the centrifugal force exerted by the blades to the interior of the ring; a fibrous composite reinforcing ring extending around the exterior of the mounting ring and between the arms to reinforce the mounting ring against centrifugal forces; and a standoff ring disposed between the mounting ring and the reinforcing ring and shaped to be elactically yieldable in the radial direction.

9. A rotor as recited in claim 8 in which the standoff ring has openings for the said blade-root arms.

10. A turbomachine rotor structure substantially as hereinbefore particularly described with reference to, and as shown in the accompanying drawings.

D. H. O. WORKMAN,
Chartered Patent Agent.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1971.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

Fig.1.

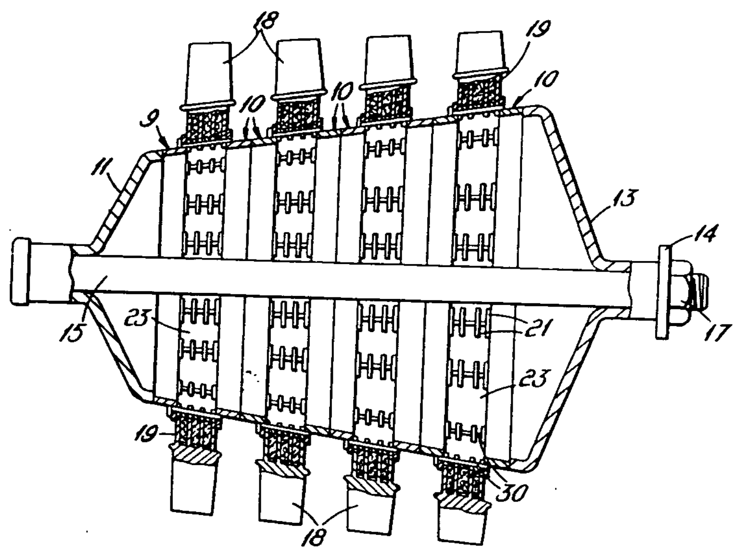

Fig.2.

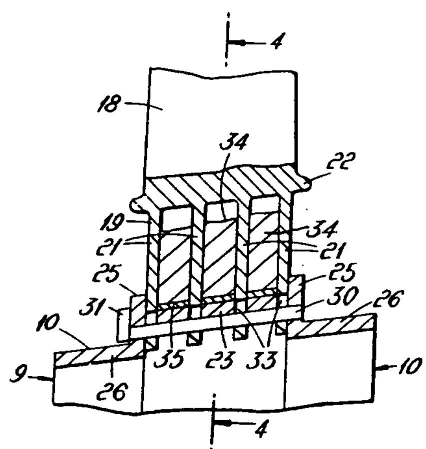

Fig.3.

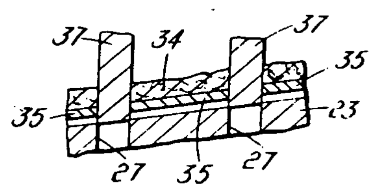

Fig.4.

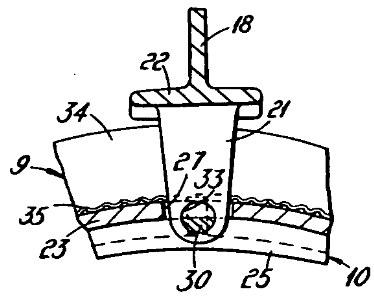

Fig.5.

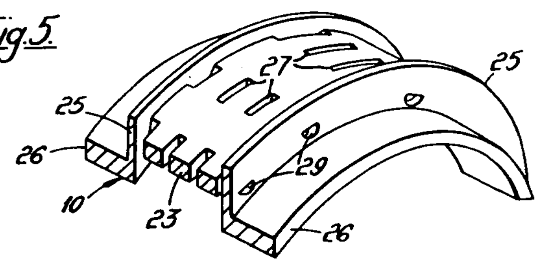

Fig.6.